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AIR FORCE RESEARCH LABORATORY

Birdstrike Fragment Capture Calibration Methods

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Approved for public release; distribution is unlimited.

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Biomechanics Branch
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NOTICES

TECHNICAL REVIEW AND APPROVAL

AFRL-HE-WP-SR-2005-0002

The voluntary informed consent of the subjects used in this research was obtained as required by Air Force Instruction 40-402.

This report has been reviewed by the Office of Public Affairs (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

FOR THE DIRECTOR

//Signed//

MARK M. HOFFMAN
Deputy Chief, Biosciences and Protection Division
Air Force Research Laboratory

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14. ABSTRACT

AFRL/HEPA provided manikin support for fragment capture and analysis of two T-38 birdstrike tests in support of the Ogden Air Logistics Center (ALC) at Hill AFB. The first test occurred on 6 December 2002 in Huntsville, AL at PPG's test facilities. The second test occurred on 26 February 2003 at the Sierracin/Sylmar Corporation, Sylmar, CA. Two foam calibration methods to relate penetration depths and striking velocity were used for the prediction of injury potential. The first, using high-speed video, was deemed overly time-consuming with an overuse of manpower. The second method, using a light gate device, is a viable and easy method of foam calibration needing only one man for both testing and analysis. The current setup has a limited range of projectile sizes and velocities that can be used. A better launching device is necessary for a broader range of fragment sizes and velocities.

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Birdstrike, Fragment Capture

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PREFACE

The testing described in this report was conducted by personnel of the Biomechanics Branch of the Human Effectiveness Directorate of the Air Force Research Laboratory (HEPA) to provide manikin support for fragment capture and analysis of two T-38 birdstrike tests in support of the Odgen Air Logistics Center (ALC) at Hill AFB. The first test occurred on 6 December 2002 in Huntsville, AL at PPG's test facilities. The second test occurred on 26 February 2003 at the Sierracin/Sylmar Corporation, Sylmar, CA. Additional testing was performed in-house to further refine foam calibration methods. This work was performed under work unit 71840205.

Joseph Pellettiere of AFRL/HEPA served as the principal investigator and project manager, with Chris Albery of General Dynamics and Nathan Wright as associate investigators.

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INTRODUCTION AND OVERVIEW

The design work for the T-38 bird-resistant windscreen started back in the late 1980s. The old acrylic windshield was qualified to resist a four-pound bird at 200 knots. The new bird-resistant windshield was designed to resist a four-pound bird at 400 knots. The testing to qualify the windshield for a four-pound bird at 400 knots was concluded in 1995. All US-owned T-38's were retrofitted with the new bird-impact-resistant windshield. In the late 1990s, the T-38 underwent testing on its Avionics Upgrade Program upgrade (AUP) that included a Heads-Up Display (HUD). Since the HUD was positioned close to the windshield, it was decided that bird-impact testing needed to be conducted to verify pilot protection. A glass fragment capture device was used to determine pilot safety. The first two bird impacts were failures. The HUD glass was redesigned to shatter into smaller pieces, thus not becoming lethal projectiles. The HUD brackets were redesigned to collapse during an impact rather than remain stiff and puncture the windscreen. The glass fragment capture device was and is critical to determining if the particles of HUD or other items become lethal projectiles to the pilot.

Much work has been performed historically to look at human injury during birdstrike. The Air Force was instrumental in formulating birdstrike testing methods during the 1970s and developed the "chicken gun" at Arnold Engineering Development Center in 1971-1972 (Bokulich). Further testing in 1977 investigated human head and neck kinematic response and canopy dynamics during birdstrike (Specker).

This report outlines the glass fragment capture techniques used for two birdstrike tests in the Fall of 2002 and Spring of 2003. It also reports on the foam calibration techniques necessary to analyze fragment capture.

TEST DESCRIPTION

Projectile collection techniques were developed by the Armstrong Laboratory and the University of Dayton Research Institute (UDRI) in the mid 1990s. Velocity and penetration correlation for different projectile masses was made using a velocity retardation model used by the Army Research Laboratory (ARL) COMPUTERMAN wound simulation program that accounts for different shapes and masses of projectiles (Saucier). The governing equation is:

$$-\mu\frac{dv}{dx} = av + b + \frac{c}{v} \qquad (1)$$

where μ is the mass of the projectile divided by the presented area of the projectile, $\frac{dv}{dx}$ is the change in velocity over distance, and v is the velocity . The arbitrary constants a, b, and c are based on the density of the foam sample and are weakly dependent on the projectile. The arbitrary constants are found by curve-fitting techniques when μ *r (where r is the negative striking velocity divided by the penetration depth) is plotted against the average velocity of the projectile. If the presented area of the projectile cannot be measured directly, it can be derived from the relationship

$$A_p = \gamma \left(\frac{m}{\rho} \right)^{\frac{2}{3}} \quad (2)$$

where γ is a shape factor for the given projectile, m is the mass, and ρ is the density.

An in-house foam calibration method was not in place during these birdstrike tests, so one needed to be developed before more testing could be conducted. First, a good projectile launcher is necessary that can utilize different test projectile shapes and weights. The velocity must be controllable, either directly on the launcher or by putting various mediums in front of the nozzle such as paper and plastic. Both a spring-powered BB gun and an electric low-speed plastic BB shooter were used in the foam calibration. These devices can shoot three different projectiles including a round copper BB, a flat lead pellet, and a rounded-tip lead pellet. The plastic BB shooter is limited to only round plastic BBs. Various amounts of thin plastic were put over the nozzles to slow the projectiles. Only horizontal motion was considered since vertical motion due to gravity is extremely small in magnitude because of the short distance between the nozzle and the foam.

Two different foam calibration methods were tested. The first method utilized a high-speed camera (Figure 1) and was used to calibrate the 0.85 lb/ft^3 foam used during the birdstrike tests. A grid was placed behind the projectile path, and the displacement between adjacent frames was measured. This method was very time-consuming and involved significant effort. Finding adjacent frames in which the projectile could be seen was a time-consuming process as the view was not always in focus and the projectile was blurred. The depth of the projectile was found by inserting a long, thin instrument into the projectile hole and measuring the length of the submerged instrument. Half the diameter of the projectile was added to the measurement to find the position of the center relative to the surface of the foam.

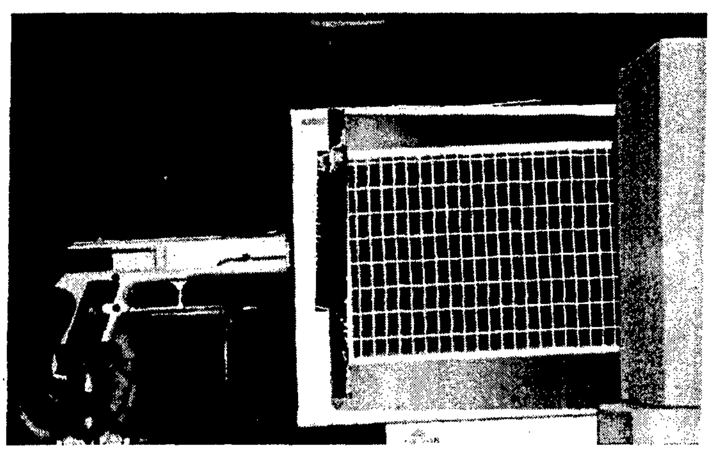

Figure 1. High-speed Camera Calibration Method

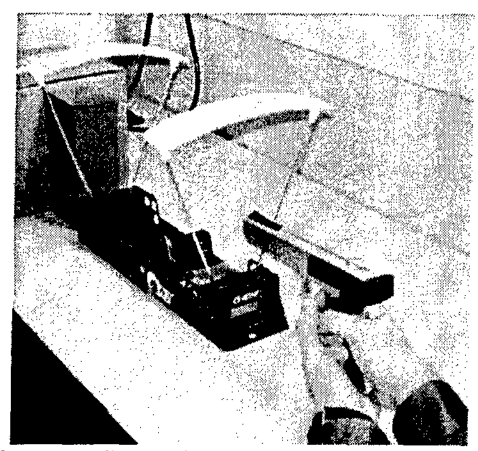

Figure 2. Light Gate Calibration Method

The second method used a paint ball/archery projectile speed measuring device. The device is often used for calibrating the speed of a paint ball gun as velocity limitations are often set by paint ball fields. The accuracy of the device is +/- 0.5% of the measured velocity. The device has two light gates a fixed distance apart with an electronic readout. Proper lighting is crucial in getting good data. After firing, the projectile depth in the foam is probed. This method is quicker than the first and can be done by one person as the velocity is measured by the device directly and lengthy video analysis and test support are not needed.

Three different densities of phenolic foams were tested for comparison using the light gate method. The foams are commonly used as floral foams and are available from local retailers. The densities tested were 1.1lb/ft^3, 1.86lb/ft^3, and 2.02lb/ft^3. The calibration curve derived from Equation 1 is unique to the density of the foam. The calibration coefficients in Table 1 are curve fitting coefficients that are used in Equation 1. Due to the limited range in projectile velocities from the testing equipment, only small sections of the complete calibration curves are shown, though velocities outside the range tested can be extrapolated. From the chart it is shown that the calibration curves can be shifted up and down with different slopes for the range of velocities tested.

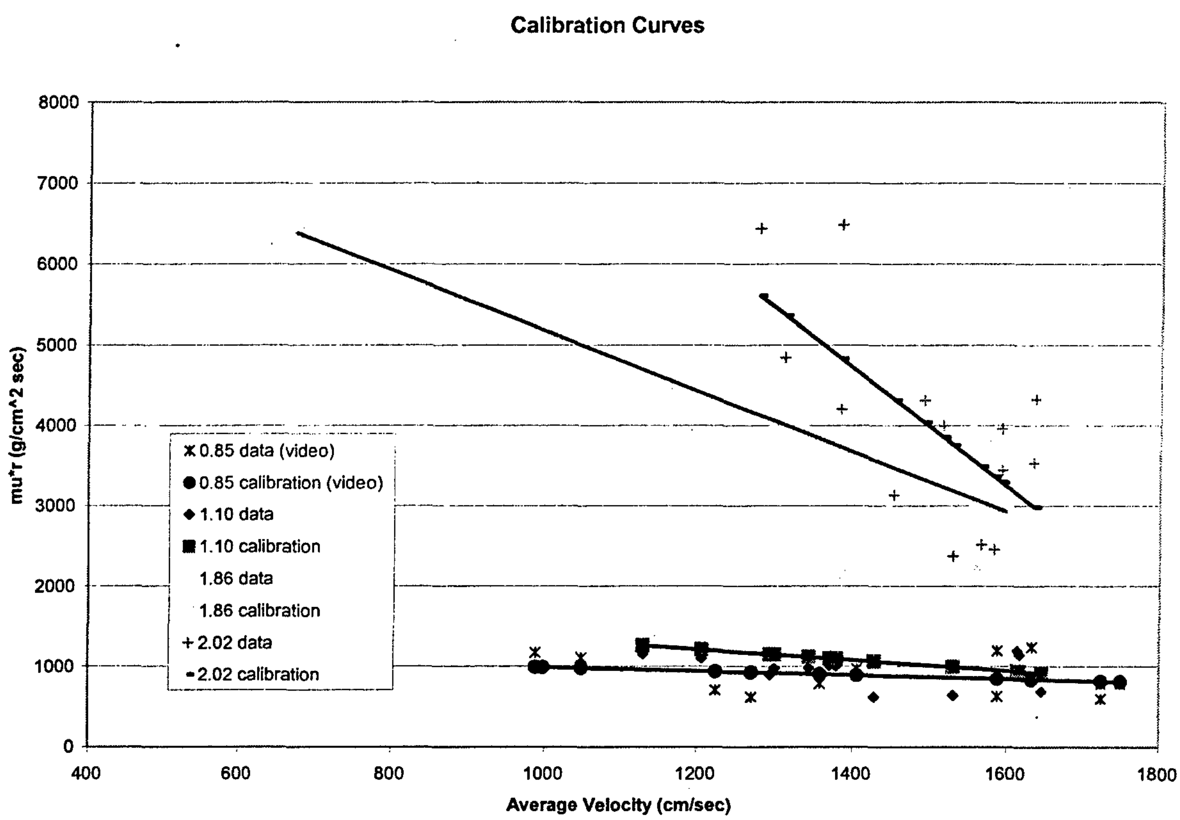

Figure 3. Calibration Curves for Different Foams

Table 1. Calibration Coefficients

Density (lb/ft^3)	0.85	1.10	1.86	2.02
a	-0.246	-0.670	-3.746	-7.347
b	1239.507	2019.926	8914.071	14987.874
c	1.945	2.875	16.797	20.429

BIRDSTRIKE TESTING

Two separate birdstrike tests were conducted using fragment capture techniques. The first test occurred on 6 December 2002 in Huntsville, AL at PPG's test facilities. The second test occurred on 26 February 2003 at the Sierracin/Sylmar Corporation, Sylmar, CA. The Ogden Air Logisitics Center (ALC) developed a test plan for conducting the actual birdstrike test according to ASTM F 330-89. The methods outlined here will discuss only the fragment analysis method.

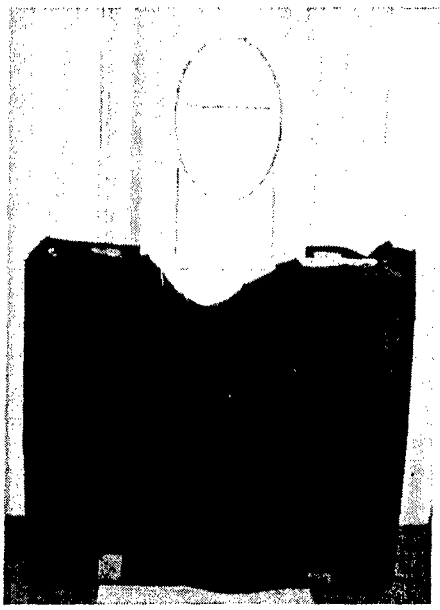

Figure 4. Foam Manikin Ready for Testing

A phenolic foam manikin was used for this testing, obtained from Ludwig Inc, Waldo, AR. Measurements determined that the density of the foam was approximately 0.85 lb/ft^3.

Table 2. Manikin Anthropometry

Sitting Height	40.0"
Shoulder Height, Acromion	26.9"
Shoulder Breadth, Bideltoid	22.6"
Chest Breadth	15.5"
Waist Breadth at Navel	15.2"
Head Breadth	6.1"
Chin to Top of Head	9.2"
Neck Breadth	5.6"

Anthropometry measurements were obtained for the expected crewmember size, and the foam was cut to represent this occupant (Figure 4). The anthropometry is based on a JPATS Case 5 manikin (Table 2).

The foam manikin was covered with an inner single-layer cotton t-shirt and an outer single-layer Nomex material to simulate the use of a flight suit. A stiffer foam material was placed on the back and the sides of the manikin to prevent the loss of any fragments that might fully penetrate the foam and to allow easier handling.

The manikin was placed in the T-38 cockpit with the back of the manikin resting against the seat rails (Figure 5) or seat back in the approximate position a pilot would sit. The bottom of the manikin rested on a piece of steel placed at the approximate height of the seat pan to represent an in-place seat. A laser mounted inside the bird cannon was used to determine the design eye height (vertical position). This laser marked the expected target location by directing a beam through the windshield and HUD onto the manikin. The position of the manikin was then adjusted such that the design eye and the anticipated target were aligned. To adjust the vertical position, the base of the manikin was trimmed and wedged. A set of straps secured the manikin into position.

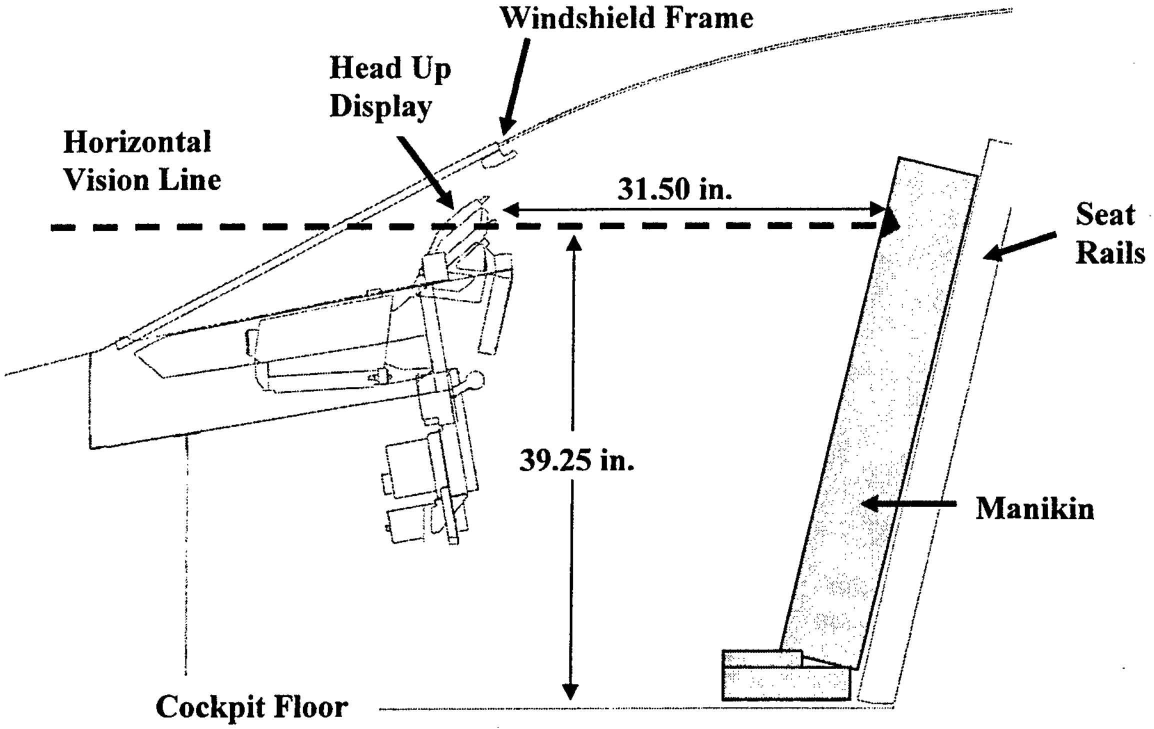

Figure 5. Manikin Setup in T-38 Cockpit - Sierracin

During the test the manikin captured the debris field from the resulting impact of the bird and windshield with the HUD. During the first test, several penetrating small holes could be immediately identified in the manikin. Also, the resulting fracture of the acrylic canopy caused a large piece of the canopy to strike and indent the face region of the manikin. Since the canopy was secured to the cockpit during the test (not jettisoned), it was determined that any damage resulting from the canopy would not be included in the analysis. During the second test no analyzable fragments were captured.

RESULTS

A coordinate system was overlaid on the manikin (Figure 6) and then inspected for locations of potential fragment recovery (Figure 7). A total of ten fragments were recovered from the manikin during the first test and each corresponding location was measured (Table 2). The velocities, mass, density, shape factor, and penetration depth of each fragment (Table 3) were entered into the COMPUTERMAN model (Saucier).

Table 3. Recovered Fragment Locations

Fragment	X (in.)	Y (in.)	Z (in.)	Position
1	0.000	1.500	-0.750	Head
2	-1.750	1.325	-1.750	Head
3	-2.875	1.500	-7.750	Head
4	0.750	0.325	-11.750	Neck
5	2.500	0.125	-14.500	Neck
6	1.500	1.000	-21.250	Chest
7	-1.250	1.375	-11.750	Neck
8	-2.500	1.125	-10.250	Neck
9	0.000	1.500	-6.250	Head
10	-1.250	1.125	-3.500	Head

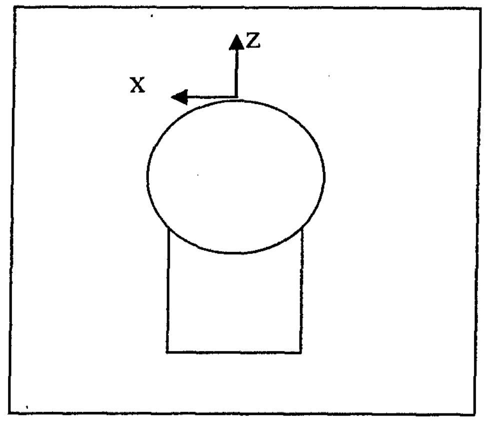

Figure 6. Manikin Coordinate

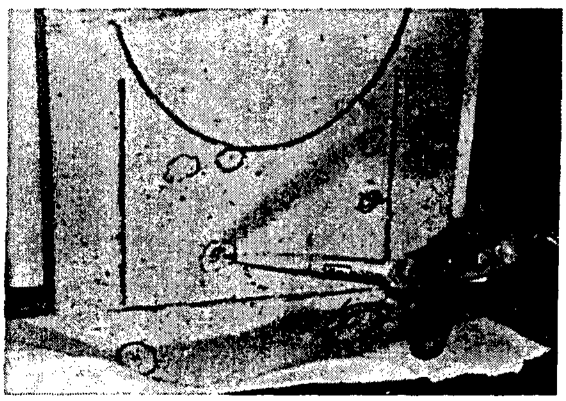

Figure 7. Post Test Inspection of Foam

Due to the differing anthropometric measurements of the manikin and COMPUTERMAN model, the head and neck of the manikin were scaled to that of the model. The projectile penetration locations were scaled accordingly. Fragment 3 was still not on the COMPUTERMAN head after scaling, so it was moved to the closest position on the head.

The fragment velocities were calculated using the Shultz et al. constants in Equation 1. Using the Shultz constants (based on a higher density foam) resulted in higher calculated velocities for the glass fragments captured in the foam during the tests. This method was deemed acceptable as it would yield a conservative, worst-case result. If any one fragment significantly increased the probability of injury using the Schultz constants, further investigation would be undertaken and the projectile evaluated again using the constants calculated in-house. In addition, the corner-forward cube shape factor, γ, was used in Equation 2 to give the largest estimated frontal area and a worst-case scenario. No fragment produced any injury-causing degradation in performance. Refer to Appendix for detailed analysis.

Table 4. Calculated Fragment Velocities

Fragment	Mass (g)	Density (lb/ft^3)	Shape Factor	Penetration Depth (cm)	Effective Area (in^2)	Mu (g/cm^2)	Velocity (km/s)
1	0.10	157.00	1.73	3.81	0.03	0.50	0.083
2	0.10	157.00	1.73	3.37	0.03	0.50	0.080
3	0.05	157.00	1.73	3.81	0.02	0.39	0.088
4	0.90	157.00	1.73	0.83	0.14	1.03	0.029
5	0.10	157.00	1.73	0.32	0.03	0.50	0.026
6	0.70	157.00	1.73	2.54	0.11	0.95	0.056
7	0.15	157.00	1.73	3.49	0.04	0.57	0.078
8	0.05	157.00	1.73	2.86	0.02	0.39	0.082
9	0.05	157.00	1.73	3.81	0.02	0.39	0.088
10	0.05	157.00	1.73	2.86	0.02	0.39	0.082

For the second birdstrike test, two chicken fragments were extracted from the foam, but no glass or other HUD fragments were found for extraction. The chicken fragments were not analyzed by COMPUTERMAN for injury potential due to their extremely small mass.

Based upon the COMPUTERMAN analysis, the survivability of the pilot due to all the fragments was calculated to be greater than 99% for the first test using the Schultz et al. constants. Skin penetration was estimated at greater than 50% probability. For this case it is a non-issue as the fragment masses are very small. Using the Schultz data gave higher velocities than the in-house calibration of the foam, allowing for an extra factor of safety.

Note that only fragments from the HUD were included in the analysis and damage resulting from impact with the canopy was not included. In addition, this analysis did not measure any impact injuries but only the resulting penetrations. The analysis did not include the effects of pilot interaction from being impacted. With these limitations in mind, it can be expected that this crewmember would have fully survived from the debris field caused by this birdstrike impact.

Neither glass nor HUD fragments were found in the manikin during the second test. Two chicken fragments were extracted from the manikin but these fragments were not analyzed with COMPUTERMAN to determine injury potential. The test is considered successful in that no fragments from the HUD were found in the manikin. It is unlikely that the pilot would have been incapacitated due to the debris field caused from this strike.

SUMMARY

Two birdstrike tests were completed using fragment capture methods. Fragment extraction and analysis were performed on each fragment. For the first test, the survivability of all the fragments was calculated to be greater than 99%. For the second test, no HUD fragments were captured. Two foam calibration methods to relate penetration depth and striking velocity were used for the prediction of injury potential. The first, using high-speed video, was deemed overly time-consuming with an overuse of manpower. The second method, using a light gate device, is a viable and easy method of foam calibration needing only one person for both testing and analysis. The current setup is limited in that a limited range of projectile sizes and velocities can be used. A better launching device is necessary for a broader range of fragment sizes and velocities.

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APPENDIX A: COMPUTERMAN FRAGMENT ANALYSIS

```
fragment 1 old calibration

ARL ComputerMan (C++/MFC Version 1.0)
Fri Jan 31 13:58:51 2003

Single Shot Mode

# Mass (grains):                    1.543
# Striking Velocity (m/sec):        82.950
# Shape Factor (dimensionless):     1.730
# Density (grams/cc):               2.810

Shotline Origin (mm): 268.000 195.000 1736.000
Azimuth (degrees):    0.000
Elevation (degrees):  0.000

Not wearing body armor

Using the rule F + F = T in combining limb states:
Post-      Biomechanical State    Degradation in
Wounding   (Limb Dysfunction)     Performance (%)
Time       LArm RArm LLeg RLeg     A   D   R   S
--------   ---- ---- ---- ----    --- --- --- ---
  30 sec     0    0    0    0      0   0   0   0
   5 min     0    0    0    0      0   0   0   0
  30 min     0    0    0    0      0   0   0   0
  12 hrs     0    0    0    0      0   0   0   0
  24 hrs     0    0    0    0      0   0   0   0
  5 days     0    0    0    0      0   0   0   0


Survival Probability (using ISS) = 0.992
Survival Probability (using AP)  = 0.990


Single Shot Completed
CPU seconds = 0.201
```

```
fragment 2 old calibration

ARL ComputerMan (C++/MFC Version 1.0)
Fri Jan 31 14:00:44 2003

Single Shot Mode

# Mass (grains):                    1.543
# Striking Velocity (m/sec):        79.960
# Shape Factor (dimensionless): 1.730
# Density (grams/cc):               2.810

Shotline Origin (mm): 220.000 200.000 1717.000
Azimuth (degrees):    0.000
Elevation (degrees):  0.000

Not wearing body armor

Using the rule F + F = T in combining limb states:
Post-       Biomechanical State    Degradation in
Wounding    (Limb Dysfunction)     Performance (%)
Time        LArm RArm LLeg RLeg      A   D   R   S
--------    ---- ---- ---- ----    --- --- --- ---
  30 sec       0    0    0    0      0   0   0   0
   5 min       0    0    0    0      0   0   0   0
  30 min       0    0    0    0      0   0   0   0
  12 hrs       0    0    0    0      0   0   0   0
  24 hrs       0    0    0    0      0   0   0   0
  5 days       0    0    0    0      0   0   0   0


Survival Probability (using ISS) = 0.992
Survival Probability (using AP)  = 0.990


Single Shot Completed
CPU seconds = 0.040
```

fragment 3 old calibration

projectile penetration location moved to nearest point on head

ARL ComputerMan (C++/MFC Version 1.0)
Fri Jan 31 14:02:59 2003

Single Shot Mode

Mass (grains): 0.772
Striking Velocity (m/sec): 88.190
Shape Factor (dimensionless): 1.730
Density (grams/cc): 2.810

Shotline Origin (mm): 198.000 215.000 1607.000
Azimuth (degrees): 0.000
Elevation (degrees): 0.000

Not wearing body armor

Using the rule F + F = T in combining limb states:

Post-Wounding Time	Biomechanical State (Limb Dysfunction) LArm	RArm	LLeg	RLeg	Degradation in Performance (%) A	D	R	S
30 sec	0	0	0	0	0	0	0	0
5 min	0	0	0	0	0	0	0	0
30 min	0	0	0	0	0	0	0	0
12 hrs	0	0	0	0	0	0	0	0
24 hrs	0	0	0	0	0	0	0	0
5 days	0	0	0	0	0	0	0	0

Survival Probability (using ISS) = 0.992
Survival Probability (using AP) = 0.990

Single Shot Completed
CPU seconds = 0.060

fragment 4 old calibration

ARL ComputerMan (C++/MFC Version 1.0)
Fri Jan 31 14:04:29 2003

Single Shot Mode

```
# Mass (grains):                    13.887
# Striking Velocity (m/sec):        29.140
# Shape Factor (dimensionless):     1.730
# Density (grams/cc):               2.810

Shotline Origin (mm): 283.000 180.000 1548.000
Azimuth (degrees):    0.000
Elevation (degrees):  0.000
```

Not wearing body armor

Using the rule F + F = T in combining limb states:

Post-Wounding Time	Biomechanical State (Limb Dysfunction) LArm	RArm	LLeg	RLeg	Degradation in Performance (%) A	D	R	S
30 sec	0	0	0	0	0	0	0	0
5 min	0	0	0	0	0	0	0	0
30 min	0	0	0	0	0	0	0	0
12 hrs	0	0	0	0	0	0	0	0
24 hrs	0	0	0	0	0	0	0	0
5 days	0	0	0	0	0	0	0	0

Survival Probability (using ISS) = 0.989
Survival Probability (using AP) = 0.990

Single Shot Completed
CPU seconds = 0.030

```
fragment 5 old calibration

ARL ComputerMan (C++/MFC Version 1.0)
Fri Jan 31 14:05:38 2003

Single Shot Mode

# Mass (grains):                    1.543
# Striking Velocity (m/sec):        25.580
# Shape Factor (dimensionless):     1.730
# Density (grams/cc):               2.810

Shotline Origin (mm): 321.000 165.000 1515.000
Azimuth (degrees):    0.000
Elevation (degrees):  0.000

Not wearing body armor

Using the rule F + F = T in combining limb states:
Post-      Biomechanical State      Degradation in
Wounding   (Limb Dysfunction)       Performance (%)
Time       LArm RArm LLeg RLeg       A   D   R   S
--------   ---- ---- ---- ----      --- --- --- ---
  30 sec     0    0    0    0        0   0   0   0
   5 min     0    0    0    0        0   0   0   0
  30 min     0    0    0    0        0   0   0   0
  12 hrs     0    0    0    0        0   0   0   0
  24 hrs     0    0    0    0        0   0   0   0
  5 days     0    0    0    0        0   0   0   0


Survival Probability (using ISS) = 0.992
Survival Probability (using AP)  = 0.990


Single Shot Completed
CPU seconds = 0.070
```

```
fragment 6 old calibration

ARL ComputerMan (C++/MFC Version 1.0)
Fri Jan 31 14:06:58 2003

Single Shot Mode

# Mass (grains):                    10.801
# Striking Velocity (m/sec):        55.670
# Shape Factor (dimensionless):     1.730
# Density (grams/cc):               2.810

Shotline Origin (mm): 306.000 235.000 1325.000
Azimuth (degrees):    0.000
Elevation (degrees):  0.000

Not wearing body armor

Using the rule F + F = T in combining limb states:
Post-      Biomechanical State     Degradation in
Wounding   (Limb Dysfunction)      Performance (%)
Time       LArm RArm LLeg RLeg      A   D   R   S
--------   ---- ---- ---- ----     --- --- --- ---
  30 sec     0    0    0    0       0   0   0   0
   5 min     0    0    0    0       0   0   0   0
  30 min     0    0    0    0       0   0   0   0
  12 hrs     0    0    0    0       0   0   0   0
  24 hrs     0    0    0    0       0   0   0   0
   5 days    0    0    0    0       0   0   0   0

Survival Probability (using ISS) = 0.989
Survival Probability (using AP)  = 0.990

Single Shot Completed
CPU seconds = 0.030
```

```
fragment 7 old calibration

ARL ComputerMan (C++/MFC Version 1.0)
Fri Jan 31 14:08:09 2003

Single Shot Mode

# Mass (grains):                    2.314
# Striking Velocity (m/sec):        77.530
# Shape Factor (dimensionless):     1.730
# Density (grams/cc):               2.810

Shotline Origin (mm): 241.000 180.000 1548.000
Azimuth (degrees):    0.000
Elevation (degrees):  0.000

Not wearing body armor

Using the rule F + F = T in combining limb states:
Post-      Biomechanical State    Degradation in
Wounding   (Limb Dysfunction)     Performance (%)
Time       LArm RArm LLeg RLeg     A   D   R   S
--------   ---- ---- ---- ----    --- --- --- ---
  30 sec     0    0    0    0      0   0   0   0
   5 min     0    0    0    0      0   0   0   0
  30 min     0    0    0    0      0   0   0   0
  12 hrs     0    0    0    0      0   0   0   0
  24 hrs     0    0    0    0      0   0   0   0
   5 days    0    0    0    0      0   0   0   0

Survival Probability (using ISS) = 0.989
Survival Probability (using AP)  = 0.990

Single Shot Completed
CPU seconds = 0.030
```

fragment 8 old calibration

ARL ComputerMan (C++/MFC Version 1.0)
Fri Jan 31 14:09:24 2003

Single Shot Mode

```
# Mass (grains):                     0.772
# Striking Velocity (m/sec):         81.600
# Shape Factor (dimensionless): 1.730
# Density (grams/cc):                2.810

Shotline Origin (mm): 214.000 215.000 1566.000
Azimuth (degrees):    0.000
Elevation (degrees):  0.000
```

Not wearing body armor

Using the rule F + F = T in combining limb states:

Post-Wounding Time	Biomechanical State (Limb Dysfunction)				Degradation in Performance (%)			
	LArm	RArm	LLeg	RLeg	A	D	R	S
30 sec	0	0	0	0	0	0	0	0
5 min	0	0	0	0	0	0	0	0
30 min	0	0	0	0	0	0	0	0
12 hrs	0	0	0	0	0	0	0	0
24 hrs	0	0	0	0	0	0	0	0
5 days	0	0	0	0	0	0	0	0

Survival Probability (using ISS) = 0.992
Survival Probability (using AP) = 0.990

Single Shot Completed
CPU seconds = 0.060

fragment 9 old calibration

ARL ComputerMan (C++/MFC Version 1.0)
Fri Jan 31 14:10:26 2003

Single Shot Mode

Mass (grains): 0.772
Striking Velocity (m/sec): 88.190
Shape Factor (dimensionless): 1.730
Density (grams/cc): 2.810

Shotline Origin (mm): 268.000 215.000 1634.000
Azimuth (degrees): 0.000
Elevation (degrees): 0.000

Not wearing body armor

Using the rule F + F = T in combining limb states:

Post-Wounding Time	Biomechanical State (Limb Dysfunction)				Degradation in Performance (%)			
	LArm	RArm	LLeg	RLeg	A	D	R	S
30 sec	0	0	0	0	0	0	0	0
5 min	0	0	0	0	0	0	0	0
30 min	0	0	0	0	0	0	0	0
12 hrs	0	0	0	0	0	0	0	0
24 hrs	0	0	0	0	0	0	0	0
5 days	0	0	0	0	0	0	0	0

Survival Probability (using ISS) = 0.992
Survival Probability (using AP) = 0.990

Single Shot Completed
CPU seconds = 0.030

```
fragment 10 old calibration

ARL ComputerMan (C++/MFC Version 1.0)
Fri Jan 31 14:11:29 2003

Single Shot Mode

# Mass (grains):                    0.772
# Striking Velocity (m/sec):        81.600
# Shape Factor (dimensionless): 1.730
# Density (grams/cc):               2.810

Shotline Origin (mm): 233.000 215.000 1685.000
Azimuth (degrees):     0.000
Elevation (degrees):  0.000

Not wearing body armor

Using the rule F + F = T in combining limb states:
Post-      Biomechanical State     Degradation in
Wounding   (Limb Dysfunction)      Performance (%)
Time       LArm RArm LLeg RLeg      A   D   R   S
--------   ---- ---- ---- ----     --- --- --- ---
  30 sec     0    0    0    0       0   0   0   0
   5 min     0    0    0    0       0   0   0   0
  30 min     0    0    0    0       0   0   0   0
  12 hrs     0    0    0    0       0   0   0   0
  24 hrs     0    0    0    0       0   0   0   0
  5 days     0    0    0    0       0   0   0   0

Survival Probability (using ISS) = 0.992
Survival Probability (using AP)  = 0.990

Single Shot Completed
CPU seconds = 0.030
```